INDOOR AIR QUALITY ASSESSMENT

Northbridge Middle School
171 Linwood Avenue
Whitinsville, MA 01588

Prepared by:
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Center for Environmental Health
Emergency Response/Indoor Air Quality Program
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Background/Introduction

At the request of the Northbridge Board of Health (NBOH), the Massachusetts Department of Public Health's (MDPH) Center for Environmental Health (CEH) conducted an indoor air quality assessment at the Northbridge Middle School (NMS), 171 Linwood Avenue, Whitinsville, Massachusetts. The request was prompted by concerns of water damage related to a leaking roof. On March 22 and 29, 2005, visits to conduct indoor air quality assessments were made to the NMS by Sharon Lee, an Environmental Analyst in CEH's Emergency Response/Indoor Air Quality (ER/IAQ) Program. During the visits, Ms. Lee was accompanied by Paul Halacy, Director of Buildings and Grounds and Michael Bedard, Maintenance Department, Northbridge Public Schools.

The NMS is a two-story brick building originally constructed circa 1905 as the Whitin-Lasell High School (WHS). The original NMS was constructed in 1927 adjacent to the WHS. An addition connecting the two schools was constructed in 1955. In 1986, a second addition containing the auditorium and gymnasium was constructed. Portions of the 1927 and 1955 buildings were also renovated during the construction of the 1986 addition. Portables that are used for storage were added in 1998. The middle and high school student population shared this complex until 2001. After the new Northbridge High School opened in 2001, the NMS population expanded to fill the entire building. Windows throughout the school are openable.

Methods

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were conducted with the TSI, Q-Trak, IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers (PM2.5) were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID).

Results

The school houses approximately 800 students in fifth through eighth grades, as well as approximately 80 staff members. The tests were taken during normal operations at the school. Test results appear in Tables 1 and 2.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were above 800 parts per million (ppm) in thirteen of fifty-three areas surveyed on March 22, 2005, indicating adequate ventilation in the majority of areas surveyed. On March 29, 2005, carbon dioxide levels were elevated above 800 ppm in seven of twenty-four areas (Table 2), also indicating adequate ventilation in most areas of the school surveyed on the second day of the assessment. It is important to note that on both assessment dates, many rooms were sparsely populated. This condition can greatly reduce carbon dioxide levels. Therefore, carbon dioxide levels would be expected to be higher with increased occupancy.

Fresh air in classrooms is supplied by unit ventilator (univent) systems (Picture 1). A univent draws air from outdoors through a fresh air intake located on the exterior wall of the building (Picture 2) and returns air through an air intake located at the base the unit (Figure 1). Fresh and return air are mixed, filtered, heated and provided to classrooms through an air diffuser located in the top of the unit. Some univents were off during both assessments. Obstructions to airflow, such as papers and books stored on univents and items placed in front of univent returns, were also observed in a number of classrooms (Picture 3). In order for univents to provide fresh air as designed, these units must remain activated and allowed to operate while rooms are occupied. In addition, univent intakes and diffusers must remain free of obstructions.

Mechanical exhaust ventilation is provided by wall- or ceiling-mounted exhaust vents powered by rooftop fans (Picture 4). The exhaust system was functioning at the time of assessment. However, it is important to note that the location of some exhaust vents can limit exhaust efficiency. In some areas, the exhaust ventilation function is hindered by the proximity of vents to hallway doors (Picture 5). When classroom doors are open, exhaust vents will tend to draw air from both the hallway and the classroom, reducing the effectiveness of the exhaust vent to remove common environmental pollutants. Without sufficient supply and exhaust ventilation, environmental pollutants can build up, leading to indoor air quality/comfort complaints.

Mechanical ventilation for common areas (auditorium, cafeteria, etc) and some classrooms and offices is provided by ceiling- or wall-mounted supply vents connected to rooftop air handling units (AHUs). Air is ducted back to AHUs via ceiling-mounted return vents. School occupants reported temperature control problems during the winter. According to Mr. Halacy and Mr. Bedard, concerns stem primarily from occupants in rooms with rooftop AHUs. Fresh air intakes for these AHUs are located in close proximity to the rooftop (Picture 6). During winter months, these fresh air intakes may become buried under snow. As a result, the AHUs draw in snow rather than air.

Some areas, predominately offices, did not have mechanical ventilation. Instead, these areas rely on openable windows for fresh air supply. Many of these rooms have window-mounted air conditioners equipped with a ‘fan only’ setting. To increase fresh air supplied to these areas, air conditioners can be operated on the ‘fan only’ setting.

Also of note is room 119, which is a former wood working shop that was converted into a classroom. The former shop relied heavily on pressurization for ventilation and air exchange. A passive vent is located on the wall shared with the hallway (Picture 7). A switch activated exhaust vent is located on the wall opposite the passive vent (Picture 8). When the shop was in session, the switch would open the exhaust louvers to allow pollutants to exhaust out of the building. The exhaust vent appeared to not have been activated for some time, as evidenced by boards that were placed on the outside to prevent use. In addition to this exhaust, a localized mechanical exhaust vent was observed above the doorway to the classroom (Picture 9). This ceiling exhaust is also switch activated. At the time of the assessment, this exhaust was not activated.

To maximize air exchange, the MDPH recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that HVAC systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). The last date of balancing was not known at the time of the assessment.

The Massachusetts Building Code requires that each room have a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or openable windows (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that a room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, see Appendix A.

Temperature readings ranged from 69° to 77° F on March 22, 2005 and 69° to 74° F on March 29, 2005 which were within or very close to the lower end of the MDPH recommended comfort range. The MDPH recommends that indoor air temperatures be maintained in a range of 70° to 78° F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

Relative humidity measured in the building ranged from 14 to 21 and 31 to 44 percent on March 22, 2005 and March 29, 2005 respectively, which was below the MDPH recommended comfort range in most areas. The MDPH recommends that indoor air relative humidity be maintained in a comfort range of 40 to 60 percent. Relative humidity levels in a building would be expected to drop during the heating season. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a common problem during the heating season in the northeast part of the United States.

Microbial/Mold Concerns

As previously discussed, concerns of water damage related to the roof prompted the assessment. The NMS has a history of chronic roof leaks, despite efforts to replace sections or patch areas over the years. It appears that roof leaks are active in a number of areas. Water-damaged building materials were noted in many parts of the building; however, the area of main concern is the band room. In the band room damage is most notable near the hallway entry/exit (Pictures 10 and 11). Water-damaged gypsum wallboard (GW) was observed above and below the ceiling plenum system.

In an effort to ascertain moisture content of building materials in the band room, moisture readings were taken in GW. Moisture content was measured with a Delmhorst moisture meter. The Delmhorst probe is equipped with three lights that function as visual aids that indicate moisture level. Readings that activate the green light indicate a sufficiently dry or low moisture level, those that activate the yellow light indicate borderline conditions and those that activate the red light indicate elevated moisture content. No elevated moisture readings were measured on either of the assessment dates.

In addition to the band room, materials in other rooms also sustained damage. Water-damaged GW was noted in a number of other areas. Most notably, GW is used for portions of the drop ceiling system in many areas that were water-damaged (Picture 12). GW near a skylight was also observed to be water-damaged (Picture 13). At the time of the assessment, it was unclear where the leak in this area originated. It does not appear that the skylight was the source of leakage, since there is no damage to the GW directly below and around the skylight. It is likely that a roof leak caused the damage and water traveled along a seam between two different sheets of GW.

Water-damaged and bowed ceiling tiles were observed (Picture 14). Water-damaged ceiling tiles can provide a source for mold growth and should be replaced after a water leak is discovered and repaired. Bowed tiles are an indication of chronic exposure to a humid environment. Ceiling tiles in a humid environment can absorb moisture from the ambient indoor air. Over time, these ceiling tiles begin to sag, allowing materials to move from the ceiling plenum to occupied spaces. If not dried thoroughly, under certain conditions, bowed ceiling tiles can become a source for mold growth.

The American Conference of Governmental Industrial Hygienists (ACGIH) and the US Environmental Protection Agency (US EPA) recommends that porous materials be dried with fans and heating within 24 to 48 hours of becoming wet (ACGIH, 1989; US EPA, 2001). If porous materials are not dried within this time frame, mold growth may occur. Cleaning cannot adequately remove mold growth from water-damaged porous materials. The application of a mildewcide to moldy porous materials (e.g., ceiling tiles and GW) is not recommended.

Water-damaged ceiling and wall plaster were also observed throughout the school (Picture 15). Although water-damaged ceiling plaster is not a source for mold growth, moistened dust trapped in spaces between the paint layers can become mold growth media. Other water-damaged materials included a corkboard (Picture 16) and wooden window ledges (Picture 17). Upon discovery, Mr. Halacy promptly made arrangements to remove the damaged corkboard. In one room, it appeared that a window ledge had sustained both water and termite damage. Measures should be taken to prevent further water damage and potential termite reinfestation. Open seams between the sink countertop and wall were observed in several rooms (Picture 18). If not watertight, water can penetrate through the seam, causing water damage. Water penetration and chronic exposure of porous and wood-based materials can cause these materials to swell and show signs of water damage. As previously discussed, moistened materials that are not dried within 24 to 48 hours can become potential sources for mold growth.

To determine the extent of roof damage, MDPH staff observed roof conditions on both days of the assessment. On March 22, 2005, MDPH staff observed the rubber membrane roof above the auditorium and gymnasium. The roof appeared to be patched in a number of areas. Although the roof membrane is still pliable, the patches are no longer adhering to the membrane. As a result, water can penetrate beneath patches and seals. A number of holes were also noted in the membrane. These holes can become points of water entry. Portions of the roof membrane were bubbled (Picture 19); other portions were pulling away from flashing, creating a rippling effect (Pictures 20). Damaged flashing can be a source for water penetration. Air pockets such as bubbles and ripples allow water to become trapped, damaging building materials beneath the membrane. Furthermore, water trapped beneath a membrane can migrate and disrupt adhesion of the membrane to the roof, further degrading the membrane integrity. In one case, a roof drain was observed to be clogged with leaves and other debris (Picture 21). Roof drains should be cleared of debris to prevent water pooling on the roof. Moss growth was also observed on the roof (Picture 22). Such growth is an indication that water is being retained against the roof.

On March 29, 2005, the remaining rubber membrane rooftops were observed under rain conditions. In a number of areas, the roof membrane was observed to be torn, drooping and no longer adhering to the roof surface (Pictures 23 and 24). A number of patches were also failing (Pictures 25 and 26) and flashing on the roof was damaged, thereby allowing water intrusion. Moreover, rain was observed to be pooling on a number of flat roof surfaces (Picture 27). Over time, pooling water can seep into the building, causing damage to ceiling tiles and other building materials. Freezing and thawing of pooled water can eventually degrade the integrity of the rubber membrane roof, causing cracks to form. These breaches can allow water to penetrate the building.

In addition to the normal wear and tear, the roof integrity is also compromised by degrading ventilation towers. These brick structures are severely weathered and are crumbling (Pictures 28 and 29). Debris projected from the tower can damage the rubber membrane. This debris can also become trapped under the roof membrane, further damaging the roof and providing a source for water intrusion. Furthermore, the deactivated towers appear to be serving as bird roosting sites. One tower was partially sealed at the time of the assessments (Picture 30); however, the others were not. Consideration should be given to seal these towers entirely to prevent roosting and degradation, with future plans to remove deactivated towers to prevent debris related damage to the roof membrane.

Damage was also observed on the slate roof of the 1905 portion of the building. A number of slate tiles and flashing were missing/damaged (Pictures 31 and 32). In one area, the roof cap and ridge had separated from the roof system (Picture 33). A dislodged roof ridge can be a source for water penetration. In addition, gutters to this portion of the building were significantly damaged (Picture 34). Water from missing/damaged gutters/downspouts can pool against the building, causing damage to the exterior (Picture 35). Similarly, damaged downspouts were observed on the exterior of the modular storage spaces (Picture 36).

Other sources for water penetration to the building were observed. Breaches were noted in and around the building and its windows. A rubber gasket for a classroom window was also failing (Picture 37). These breaches can serve as points for water entry into the building. Continued freezing and thawing of water during cooler months will serve only to further damage the frame. In addition, breaches can serve as points of entry or shelter for pests. The side paneling to a window bay was noted to be damaged. Since the panel is no longer intact, water can penetrate the building interior.

Shrubbery and clinging plants were growing in close proximity to slab walls. The growth of roots and tendrils against the exterior walls can bring moisture in contact with wall brick. Plant roots and tendrils can eventually penetrate the brick, leading to cracks and/or fissures in walls and/or the foundation below ground level. Over time, this process can undermine the integrity of the building envelope, providing a means of water entry into the building through capillary action through foundation concrete and masonry (Lstiburek & Brennan, 2001). Some plants are also growing in close proximity to univent fresh air intakes; odors and materials associated with plants and dirt can become entrained through the univent system.

Leaves, debris and plant growth were also noted in a subterranean pit (Picture 38). When moistened, these materials can become a source for microbial growth and odors. Leaves should be removed to prevent growth and odor production. Plant growth should be removed to prevent damage to the foundation.

Lastly, plants and potted soil were located in several classrooms. In some classrooms, plants were found on top of univents (Picture 39). Plants, soil and drip pans can serve as sources of mold growth. Plants should be properly maintained, over-watering of plants should be avoided and drip pans should be inspected periodically for mold growth. Plants should also be located away from ventilation sources to prevent aerosolization of dirt, pollen or mold.

Other Concerns

Indoor air quality can be negatively influenced by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion emissions include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, MDPH staff obtained measurements for carbon monoxide and PM2.5.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address carbon monoxide and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

ASHRAE has adopted the National Ambient Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from six criteria pollutants, including carbon monoxide and particulate matter (US

EPA, 2000a). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS levels (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000a).

Carbon monoxide should not be present in a typical, indoor environment. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. On March 22, 2005, indoor and outdoor carbon monoxide concentrations were non-detect (ND) (Table 1). On March 29, 2005, outdoor, classroom and boiler room carbon monoxide levels were ND; however, carbon monoxide levels ranging from 2.2 to 3.6 ppm were measured in the cafeteria and adjoining hallway. Elevated carbon monoxide levels were traced to the kitchen, where gas-powered appliances are located. Carbon monoxide levels in the kitchen ranged from 3.3 to 10 ppm.

At the time of assessment, the highest carbon monoxide level measured was around the exhaust hood/stove area. Gas-powered units in this area were examined, although these units did not appear to be the likely source. MDPH staff also examined ventilation in the area. Although ventilation was on at the time of assessment, louvers to some fresh air and exhaust vents were closed. Mr. Bedard opened these louvers to increase supply and exhaust to the area. Although carbon monoxide levels were reduced, they did not dissipate. MDPH staff recommended contacting the fire department and appliance servicing company to examine the gas-powered units and opening exterior doors to increase ventilation to the area. The Northbridge Fire Department was later able to determine that the fryolator, which is located approximately 10 ft in front of the exhaust hood/stove area, was the faulty appliance. Following the Northbridge Fire Department assessment on March 30, 2005, Mr. Bedard shut down the fryolator.

The US EPA has established NAAQS limits for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits to particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 micrograms per cubic meter ($\mu g/m^3$) in a 24-hour average (US EPA, 2000a). These standards were adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent, PM2.5 standard requires outdoor air particle levels be maintained below 65 $\mu g/m^3$ over a 24-hour average (US EPA, 2000a). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, MDPH uses the more protective proposed PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations were 2 $\mu g/m^3$ and 6 $\mu g/m^3$ (Tables 1 and 2). PM2.5 levels measured in the school ranged from 3 to 16 $\mu g/m^3$ and 1 to 8 $\mu g/m^3$ on March 22 and March 29, 2005, respectively (Tables 1 and 2). Frequently, indoor air levels of particulates can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulates during normal operation. Sources of indoor airborne particulate may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices, operating an ordinary vacuum cleaner and heavy foot traffic indoors. Operation of ventilation equipment is also important for diluting indoor air pollutants.

Indoor air quality can also be negatively influenced by the presence of materials containing volatile organic compounds (VOCs). VOCs are carbon-containing substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. An outdoor air sample was taken for comparison. Outdoor TVOC concentrations were ND (Tables 1 and 2). Indoor TVOC concentrations were also ND (Tables 1 and 2).

In an effort to identify materials that can potentially increase indoor TVOC concentrations, MDPH staff examined classrooms for products containing these respiratory irritants. Please note, TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use of TVOC containing products. While no TVOC levels measured exceeded background levels, materials containing VOCs were present in the school.

Several classrooms contained dry erase boards and dry erase board markers. Materials such as dry erase markers and dry erase board cleaners may contain VOCs, such as methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve (Sanford, 1999), which can be irritating to the eyes, nose and throat.

A number of cleaning agents were also observed in classrooms. Like dry erase materials, cleaning products contain VOCs and other chemicals that can be irritating to the eyes, nose and throat of sensitive individuals. Also of concern are unlabelled bottles and containers. Products should be kept in their original containers and be clearly labeled for identification purposes, especially in the event of an emergency. Of note is the storage of chemicals in the chemical closet, where ammonia was placed beside the bleach (Picture 40). Mixing these two agents will result in the production of a hazardous gas that can be cause serious eye/respiratory irritation and/or bodily harm.

Pest attractants were identified within the building. Food-based projects and re-use of food containers were noted. Proper food storage is an integral component in maintaining indoor air quality. Food should be properly stored and clearly labeled. Reuse of food containers is not recommended since food residue adhering to the surface may serve to attract pests.

Several other conditions that can potentially affect indoor air quality were identified. Upholstered furniture (i.e., couches) was noted in some areas. These upholstered items are covered with fabric that comes in contact with human skin. This type of contact can leave oils, perspiration, hair and skin cells. Dust mites feed upon human skin cells and excrete waste products that contain allergens. Furthermore, increased relative humidity levels above 60 percent can also perpetuate dust mite proliferation (US EPA, 1992). In order to remove dust mites and other pollutants, frequent vacuuming of upholstered furniture is recommended (Berry, 1994). It is also recommended that if upholstered furniture is present in schools, it should be professionally cleaned on an annual basis or every six months if dusty conditions exist (IICR, 2000).

Also of note was the amount of materials stored in some classrooms. Items were observed on windowsills, tabletops, counters, bookcases and desks. The large number of items stored in classrooms provides a source for dusts to accumulate. These items (e.g., papers, folders, boxes) make it difficult for custodial staff to clean. Items should be relocated and/or be cleaned periodically to avoid excessive dust build up. Dust was also noted on fabric partitions.

The partitions should be vacuumed periodically to prevent aerosolization when partitions are moved. Dust can be irritating to eyes, nose and respiratory tract.

Accumulated chalk dust was noted in chalk trays of some classrooms. Chalk dust is a fine particulate that can easily become aerosolized. Once aerosolized, chalk dust can become irritating to eyes and the respiratory system. Missing ceiling tiles and items hanging from the ceiling tile system were noted in a number of areas. Missing and ajar ceiling tiles create pathways for dust, dirt, odors and other pollutants to move into occupied areas.

A number of exhaust/return vents were noted with accumulated dust. If exhaust vents are not functioning, backdrafting can occur, which can re-aerosolize accumulated dust particles. Similarly, fan blades to some personal fans were also occluded with dust. When these fans are activated, dust may become aerosolized. As discussed previously, some offices are equipped with window-mounted air conditioners. These air conditioners are equipped with filters. MDPH staff observed dust occluded on AC filters, which should be cleaned or changed as per manufacturer's instructions to avoid the build up and re-aerosolization of dirt, dust and particulate matter.

Lastly, in an effort to reduce noise from sliding chairs, tennis balls had been sliced open and placed on chair legs (Picture 41). Tennis balls are made of a number of materials that are a source of respiratory irritants. Constant wearing of tennis balls can produce fibers and off-gas VOCs. Tennis balls are made with a natural rubber latex bladder, which becomes abraded when used as a chair leg pad. Use of tennis balls in this manner may introduce latex dust into the school environment. Some individuals are highly allergic to latex (e.g. spina bifida patients) (SBAA, 2001). It is recommended that the use of materials containing latex be limited in buildings to reduce the likelihood of symptoms in sensitive individuals (NIOSH, 1997). A question and answer sheet concerning latex allergy is attached as Appendix B (NIOSH, 1998). Alternative solutions to tennis balls include glides (Picture 42), which are plastic boots with felt bottoms that can be placed on chair legs.

Conclusions/Recommendations

The Northbridge Public Schools have taken a number of actions to remedy roof damage, but leaks continue to be evident. Although patches were an effective temporary solution, continued patching cannot be a solution in preventing water intrusion to the building, especially since the roofs are original to the building sections. Many of the patches were observed to be failing at the time of the assessment. The presence of weathered ventilation towers will only serve to further damage the roof membrane.

In addition to roof related problems, a number of general indoor air quality issues were observed at the NMS. Some of these conditions can be remedied by actions of building occupants. Other remediation efforts will require alteration to the building structure and equipment. A two-phase approach is required to address general indoor air quality and moisture problems experienced in the NMS. This approach consists of **short-term** recommendations to improve air quality at the school and **long-term** measures that require planning and resources to adequately address overall indoor air quality concerns.

The following **short-term** measures should be considered for implementation:

1. Operate both supply and exhaust ventilation continuously during periods of school occupancy and independent of classroom thermostat control.
2. Remove all blockages to univents.

3. Ensure classroom doors are closed in areas where exhaust vents are above/in close proximity to the hallway.
4. Use openable windows in conjunction with classroom exhaust vents to create air exchange. Care should be taken to ensure windows are properly closed at night and weekends to avoid the freezing of pipes and potential flooding.
5. To increase fresh air supplied to areas with window-mounted air conditioners, operate in the 'fan only' setting.
6. Consider adopting a balancing schedule for mechanical ventilation systems every 5 years, as recommended by ventilation industrial standards (SMACNA, 1994).
7. Consider extending the height of fresh air intakes for AHUs to prevent snow infiltration.
8. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
9. Remove, replace and/or repair water-damaged materials (e.g., ceiling tiles, GW). Examine these areas for mold growth. Disinfect areas of water leaks with an appropriate antimicrobial. Remove water-damaged materials in a manner consist with *Mold Remediation in Schools and Commercial Buildings* published by the US EPA (2001). This document can be downloaded from the US EPA: http://www.epa.gov/iaq/molds/mold_remediation.html.
10. Remove debris and ensure proper drainage to the roof and subterranean pits.

11. Consider sealing the deactivated ventilation towers to prevent debris from damaging the roof membrane, with plans for removing the towers.
12. Repair gutters and downspouts to prevent water from flowing or pooling against the building.
13. Move plants away from univents in classrooms. Ensure all plants are equipped with drip pans. Examine drip pans for mold growth and disinfect areas of water leaks with an appropriate antimicrobial where necessary. Consider reducing the number of plants.
14. Seal all utility holes, wall cracks, breaches and any other possible pathways to prevent the penetration of materials and odors into occupied areas.
15. Remove clinging plants and shrubbery in close proximity to the building exterior and univent air intakes.
16. Seal breaches, seams, and spaces between sink countertop and backsplash to prevent water damage and/or microbial growth.
17. Ensure kitchen equipment is serviced regularly. Consider obtaining a digital readout carbon monoxide detector in close proximity to the kitchen.
18. Ensure ammonia and chlorine are not placed in close proximity (e.g., above/below, adjacent). Consider conducting a chemical inventory to determine the amount and type of chemicals stored at the school. Ensure chemicals are stored properly and appropriately based on content.
19. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.
20. Clean chalkboards and dry erase board trays regularly to avoid the build-up of particulates.

21. Clean exhaust vents and fan blades periodically to prevent excessive dust build-up and aerosolization.
22. Clean upholstered furniture on the schedule recommended in this report. If not possible/practical, remove upholstered furniture from classrooms.
23. Refrain from hanging objects from the ceiling tile system.
24. Change filters for univents AHUs and air conditioners as per manufacturer's instructions or more frequently if needed, especially when conducting renovation activities. Clean interiors of units as needed during each filter change.
25. Store and label food appropriately. Refrain from re-using food containers to avoid the attraction of pests.
26. Consider discontinuing use of tennis balls on furniture and replacing tennis balls with alternative "glides".
27. In order to maintain a good indoor air quality environment on the building, consideration should be give to adopting the US EPA (2000b) document, "Tools for Schools". This document can be downloaded from the Internet: http://www.epa.gov/iaq/schools/index.html.
28. Refer to the resource manual and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These resources are located on the MDPH's website: http://mass.gov/dph/indoor_air.

The following **long-term measures** should be considered:

1. Replace both rubber membrane and slate roofs for all sections of the building to prevent additional damage to building materials.
2. Remove deactivated ventilation towers to prevent debris related damage roof surfaces.

3. Consult with an architect and/or general contractor for an evaluation of the building envelope. Consider having exterior walls re-pointed and waterproofed to prevent water intrusion.
4. Consider contacting an HVAC engineering firm to fully evaluate older ventilation systems throughout the building. Some ventilation equipment is original to the building, and repair/replacement of parts may be difficult based on age, physical deterioration and availability of parts for ventilation components.
5. Replace/repair window systems to prevent water penetration and drafts through window frames.

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Picture 1

Classroom univent

Picture 2

Univent fresh air intake on exterior wall

Picture 3

Top of univent

Obstruction to classroom univent

Picture 4

Wall-mounted exhaust

Picture 5

Exhaust vent located above hallway door

Picture 6

Fresh air intake low to rooftop, less than 6 inches in height

Picture 7

Passive wall vent in room 119

Picture 8

Switch activated wall exhaust

Picture 9

Switch activated local ceiling exhaust

Picture 10

Water damaged GW wall in band room

Picture 11

Water damaged GW above ceiling plenum in band room

Picture 12

Water damaged GW used for drop ceiling

Picture 13

Water damage near skylight

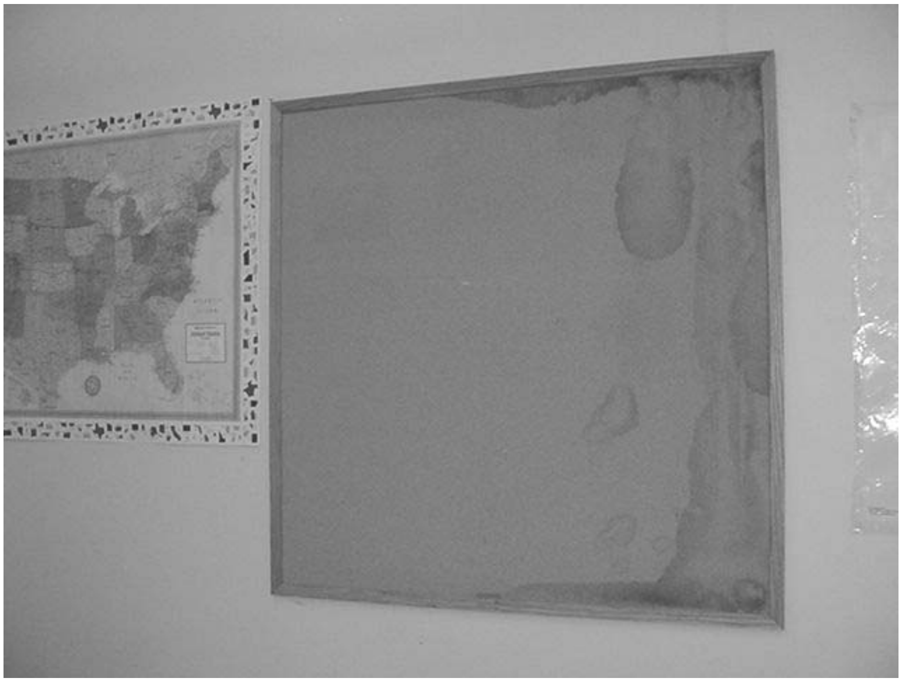
Picture 14

Bowed ceiling tiles

Picture 15

Water damaged ceiling plaster

Picture 16

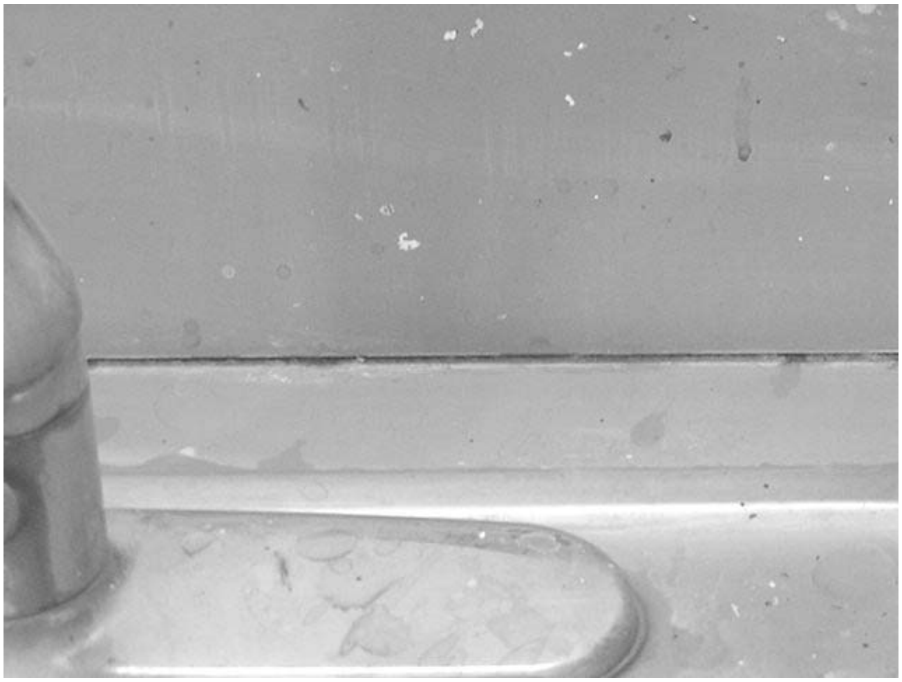


Water damaged corkboard

Picture 17

Water and termite damaged wood ledge

Picture 18



Breach between sink countertop and backsplash

Picture 19

Patches and bubble on roof membrane

Picture 20

Ripples

Picture 21

Clogged roof drain

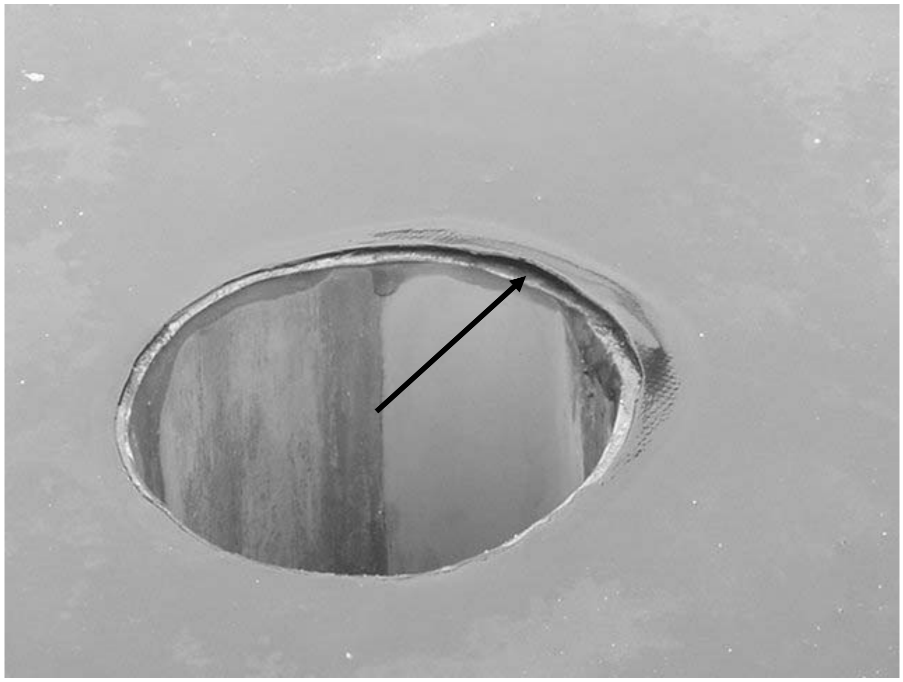
Picture 22

Moss growth on roof membrane

Picture 23

Sagging roof membrane

Picture 24

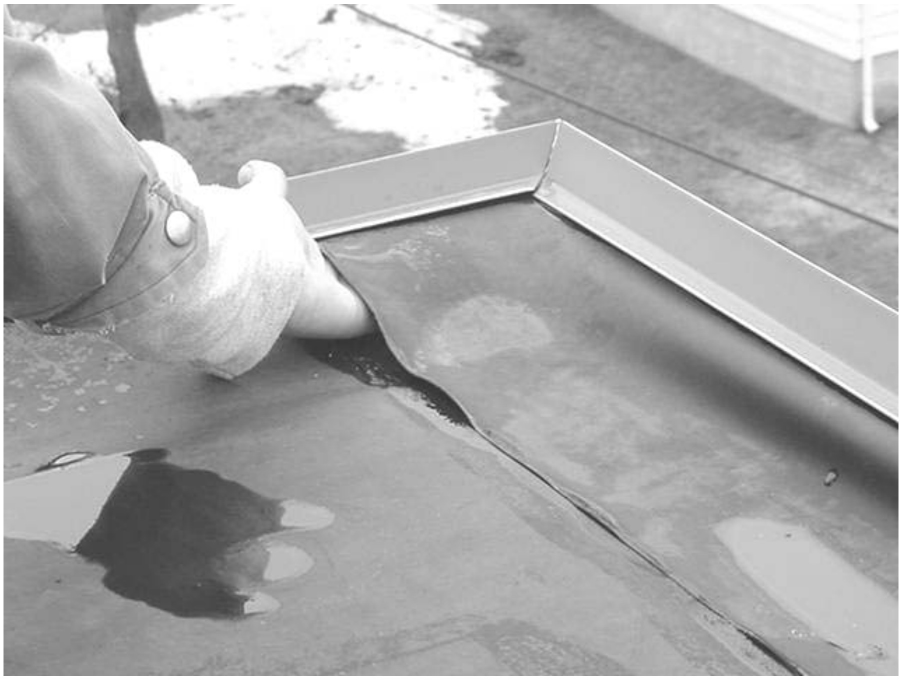


Loss of membrane adhesion to roof surface

Picture 25

Failing patch

Picture 26



Large breach in membrane

Picture 27

Pooling water on roof

Picture 28

Damaged tower

Picture 29

Debris from towers, note debris under roof membrane

Picture 30

Partially sealed tower, note evidence of slight erosion to top of tower

Picture 31

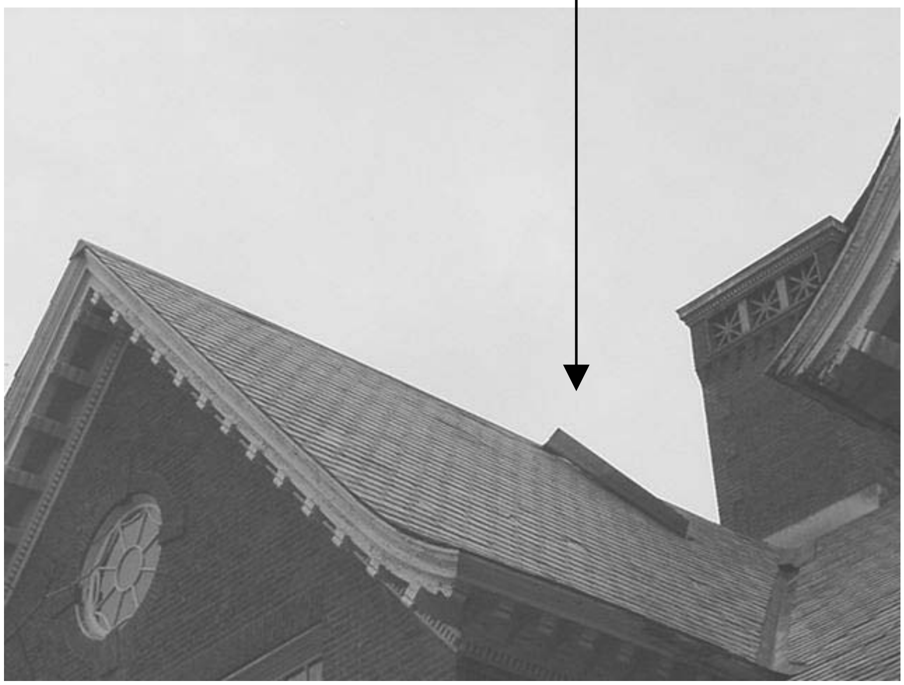
Missing and damaged slate roof tiles

Picture 32

Damaged flashing

Picture 33

Ridge cap



Damaged roof ridge

Picture 34

Damaged gutter

Picture 35

Water damaged soffit wood beneath damaged gutter

Picture 36

Missing downspout

Picture 37

Failing rubber gasket

Picture 38

Plant growth and debris in subterranean pit

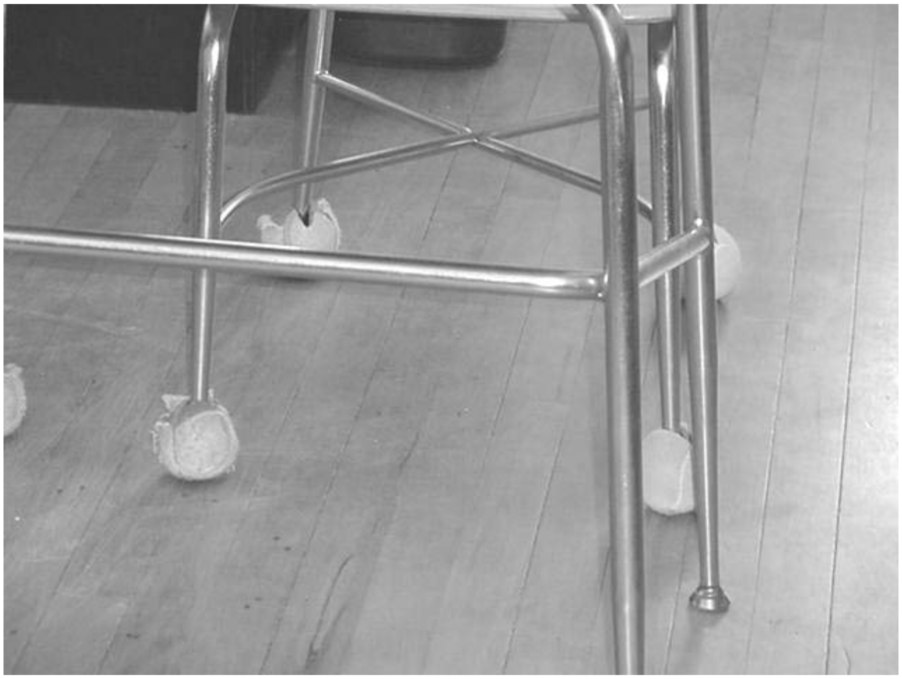
Picture 39

Plant placed in univent

Picture 40

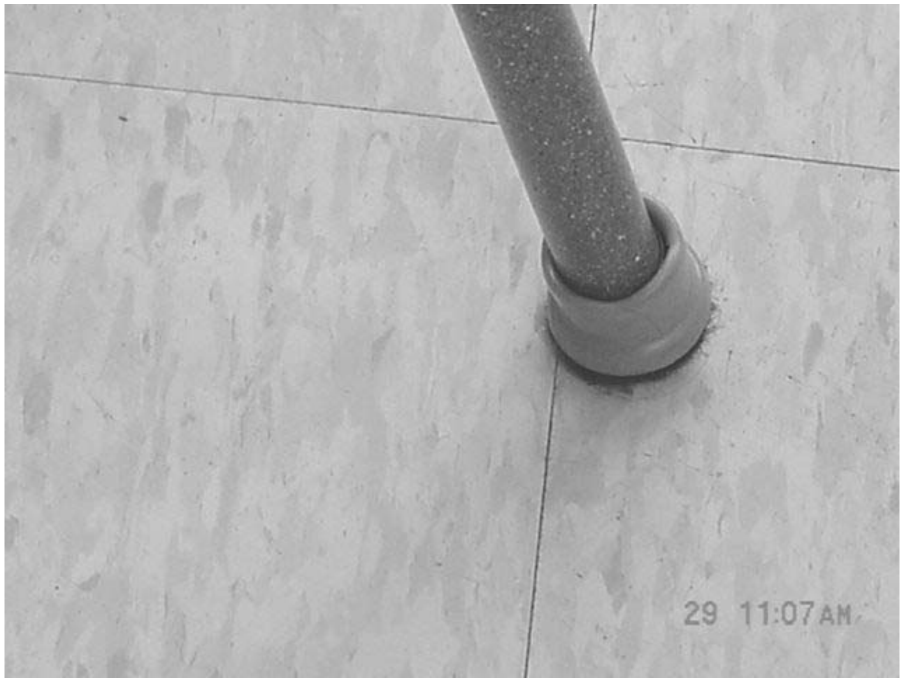
Ammonia placed next to chlorine bleach

Picture 41



Tennis balls on chair legs

Picture 42



“Glides” on bottom of chair legs

Northbridge Middle School **Indoor Air Results**

171 Linwood Ave, Whitinsville, MA 01588 **March 22, 2005**

Table 1

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
background	0	62	54	436	ND	ND	2				Overcast, light drizzle, moderate - heavy automobile traffic.
guidance office	0	74	16	475	ND	ND	4	Y # open: 1 # total: 2	N	N	Hallway DO, PF, dust, plants.
library	1	75	14	469	ND	ND	5	Y # open: 0 # total: 22	Y univent	Y ceiling	Hallway DO, #WD-CT: 1, #MT/AT : 1.
main office	1	75	19	710	ND	ND	8	N # open: 0 # total: 0	N	N	Hallway DO, window-mounted AC,
band	0	73	16	425	ND	ND	3	N # open: 0 # total: 0	Y ceiling	Y ceiling	WD-GW, #WD-CT: 2, #MT/AT: 2, WD-GW from leak in roof; WD area near door: low moisture.
201	0	74	17	446	ND	ND	8	Y # open: 0 # total: 3	Y univent	Y ceiling location	Hallway DO, CD, DEM.

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AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials

design = proximity to door
FC = food container
G = gravity
GW = gypsum wallboard
M = mechanical
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NC = non-carpeted
ND = non detect
PC = photocopier
PF = personal fan
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PS = pencil shavings

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WP = wall plaster

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Carbon Dioxide: < 600 ppm = preferred
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Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Northbridge Middle School

171 Linwood Ave, Whitinsville, MA 01588

Table 1

Indoor Air Results

March 22, 2005

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
203	1	75	17	480	ND	ND	6	Y # open: 0 # total: 5	Y univent	Y ceiling location	Hallway DO, CD, plants.
204	0	74	14	430	ND	ND	7	Y # open: 0 # total: 3	Y univent	Y ceiling location	CD, DEM.
205	11	75	17	738	ND	ND	7	Y # open: 0 # total: 6	Y univent	Y ceiling	CD, PF.
209	1	74	17	584	ND	ND	10	Y # open: 0 # total: 2	N	N	Hallway DO, Inter-room DO,
212	4	74	17	572	ND	ND	6	Y # open: 2 # total: 2	N	N	Inter-room DO,

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March 22, 2005

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									Supply	Exhaust	
213	0	75	17	488	ND	ND	6	Y # open: 0 # total: 6	Y univent items furniture	Y ceiling	CD.
220	0	75	15	619	ND	ND	5	N # open: 0 # total: 0	Y univent	Y ceiling	Inter-room DO,
221	8	73	17	540	ND	ND	6	Y # open: 1 # total: 4	Y univent	Y ceiling	CD, PF.
222	1	74	15	612	ND	ND	5	Y # open: 0 # total: 4	Y ceiling	Y ceiling	Hallway DO, PF, UF, items.
225 (computer lab)	0	76	17	524	ND	ND	5	Y # open: 0 # total: 6	Y univent (off)	Y ceiling	28 computers.

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									Supply	Exhaust	
227	22	75	17	803	ND	ND	6	Y # open: 0 # total: 6	Y univent	Y ceiling location	Hallway DO, #WD-CT: 3, CD, items.
228	0	75	14	424	ND	ND	6	Y # open: 2 # total: 5	Y univent	Y ceiling	CD, cleaners.
229	23	76	18	1017	ND	ND	11	Y # open: 0 # total: 6	Y univent	Y ceiling	CD, items.
229	23	76	18	1017	ND	ND	11	Y # open: 0 # total: 6	Y univent	Y ceiling	CD, items.
230	23	77	18	866	ND	ND	7	Y # open: 0 # total: 6	Y univent items	Y ceiling	CD, TB.
230	23	77	18	866	ND	ND	7	Y # open: 0 # total: 6	Y univent	Y ceiling	CD, TB.

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									Supply	Exhaust	
232	1	75	21	1710	ND	ND	16	Y # open: 0 # total: 2	N	N	DEM, plants.
233	5	75	15	516	ND	ND	6	Y # open: 0 # total: 6	Y univent		CD, DEM.
234	22	76	18	822	ND	ND	15	Y # open: 0 # total: 6	Y univent	Y ceiling location	Hallway DO, CD, items, FC re-uses.
235	22	76	19	946	ND	ND	12	Y # open: 0 # total: 6	Y univent	Y ceiling location	CD, PF, items.
236	18	75	16	637	ND	ND	11	Y # open: 2 # total: 6	Y univent items	Y ceiling location	CD, foot traffic.
237	23	76	17	661	ND	ND	8	Y # open: 2 # total: 6	Y univent	Y ceiling	Hallway DO, CD, plants.

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Northbridge Middle School **Indoor Air Results**

171 Linwood Ave, Whitinsville, MA 01588 **March 22, 2005**

Table 1

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
239	0	76	16	587	ND	ND	6	Y # open: 0 # total: 10	Y univent plant(s)	Y ceiling	PF, 30 computers.
241	27	77	18	808	ND	ND	5	Y # open: 0 # total: 6	Y univent	Y ceiling	Hallway DO, CD, DEM.
242	25	76	18	1076	ND	ND	11	Y # open: 0 # total: 8	Y univent	Y ceiling	Hallway DO, CD, PS.
243	12	75	16	581	ND	ND	5	Y # open: 2 # total: 12	Y univent plant(s)	Y ceiling location	Plants.
244	23	75	18	938	ND	ND	7	Y # open: 0 # total: 6	Y univent	Y ceiling	Inter-room DO, #MT/AT: 1, CD.
245	0	75	14	432	ND	ND	6	Y # open: 0 # total: 6	Y univent	Y ceiling	WD-other, CD, WD-corkboard.

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									Supply	Exhaust	
249	23	75	19	1004	ND	ND	9	Y # open: 0 # total: 7	Y univent	Y ceiling	damaged/missing window caulking/gasket, #MT/AT : 1, CD.
302	0	72	19	673	ND	ND	7	N # open: 0 # total: 0	Y univent	N	CD.
303 (Art)	23	70	21	705	ND	ND	8	Y # open: 0 # total: 5	Y univent	Y wall	Hallway DO, potter's wheel, 'aercology' air filter.
305	19	69	20	657	ND	ND	5	Y # open: 1 # total: 6	Y univent	N	Hallway DO, WD-WP, #WD-CT: 3, CD, DEM.
306	23	72	20	881	ND	ND	4	Y # open: 0 # total: 5	Y univent	N	CD.
309	0	72	15	436	ND	ND	3	Y # open: 0 # total: 4	Y univent	Y ceiling	WD-other, CD, PS, WD-window frames.

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									Supply	Exhaust	
310	26	73	17	641	ND	ND	4	Y # open: 1 # total: 8	Y univent	Y ceiling	CD.
311	22	73	16	683	ND	ND	4	Y # open: 0 # total: 2	Y univent	Y ceiling	#WD-CT: 1, CD, dry drains.
312	26	73	16	658	ND	ND	5	Y # open: 0 # total: 3	Y univent	Y ceiling	#WD-CT: 2, CD, items, dust.
313	0	75	15	443	ND	ND	4	Y # open: 0 # total: 3	Y univent	Y ceiling	
315	19	73	15	603	ND	ND	5	Y # open: 0 # total: 6	Y univent	Y ceiling	#WD-CT: 1, #MT/AT: 2, items.
316	0	75	16	465	ND	ND	5	Y # open: 1 # total: 6	Y univent	Y ceiling	Hallway DO, WD-GW, CD, DEM, WD from suspended ceiling.

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317	0	75	15	450	ND	ND	5	Y # open: 0 # total: 6	Y univent furniture	Y ceiling	Hallway DO, #WD-CT: 1, CD, PF.
319	0	75	14	427	ND	ND	4	Y # open: 0 # total: 6	Y univent boxes items furniture	Y ceiling location	Hallway DO, CD, items.
320	1	75	15	434	ND	ND	4	Y # open: 0 # total: 4	Y univent	Y ceiling location	Hallway DO, CD, peeling wall plaster.
321	0	75	15	514	ND	ND	4	Y # open: 0 # total: 6	Y univent	Y ceiling	Hallway DO, CD, DEM.
323	0	74	15	464	ND	ND	4	Y # open: 0 # total: 6	Y univent	Y ceiling location	Hallway DO, CD.

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324	0	74	16	632	ND	ND	4	Y # open: 0 # total: 0	Y univent (off) items furniture	Y ceiling location	CD.
325	0	75	17	622	ND	ND	4	Y # open: 0 # total: 6	Y univent	Y ceiling location	Hallway DO, WD-WP, CD, cleaners.
326	0	73	17	519	ND	ND	3	Y # open: 0 # total: 6	Y univent	Y ceiling	Hallway DO, CD, DEM, items.

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> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Northbridge Middle School

171 Linwood Ave, Whitinsville, MA 01588

Table 2

Indoor Air Results

March 29, 2005

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
background	0	44	68	389	ND	ND	6				overcast, light drizzle.
cafeteria	200	74	39	927	3.6	ND	8	Y # open: 1 # total: 13	Y ceiling	Y ceiling	Hallway DO, cafeteria and hallway CO: 2.2-3.6 ppm, kitchen CO 3.3 to 10ppm; faulty fryolator.
music	0	73	33	458	ND	ND	1	Y # open: 0 # total: 2	Y ceiling	Y wall	
nurse's Office	3	74	36	1045	ND	ND	4	Y # open: 0 # total: 4	N	N	PF.
special education	0	70	44	704	ND	ND	1	Y # open: 0 # total: 2	N	N	window-mounted AC, PC.

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									Supply	Exhaust	
102	2	69	33	664	ND	ND	3	Y # open: 0 # total: 2	N	N	Hallway DO, CD, DEM, cleaners.
103	27	70	41	775	ND	ND	3	Y # open: 0 # total: 5	Y ceiling		CD.
107	0	69	37	474	ND	ND	1	Y # open: 0 # total: 8	Y ceiling	Y ceiling	WD-WP.
108	2	70	39	472	ND	ND	2	Y # open: 0 # total: 4	Y univent	Y ceiling	CD.
110	0	70	40	569	ND	ND	1	Y # open: 0 # total: 0	Y univent	Y ceiling	CD.

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116A	3	73	35	873	ND	ND	8	N # open: 0 # total: 0	Y ceiling	Y ceiling	
117	0	73	33	440	ND	ND	2	Y # open: 0 # total: 9	Y univent	Y ceiling	Hallway DO, Inter-room DO, CD, DEM, items, plants.
118	0	73	33	945	ND	ND	1	Y # open: 0 # total: 3	Y univent	Y ceiling location	Inter-room DO, CD, DEM, PF.
119	1	73	31	480	ND	ND	1	Y # open: 0 # total: 4	Y ceiling	Y ceiling	Hallway DO, switch activated exhaust and supply; passive louver on wall.
120 (outer)	1	72	35	553	ND	ND	1	N # open: 0 # total: 0	N	N	Hallway DO,

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Northbridge Middle School **Indoor Air Results**

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									Supply	Exhaust	
120 (inner)	0	73	33	513	ND	ND	2	Y # open: 0 # total: 1	Y univent (weak)	N	Inter-room DO, CD, PF.
121	20	71	36	607	ND	ND	4	Y # open: 1 # total: 6	Y univent	Y ceiling	Hallway DO, PF, parking area outside classroom; occupant reports vehicle exhaust odors.
124	5	73	34	782	ND	ND	1	Y # open: 0 # total: 5	Y univent furniture	Y ceiling location	Hallway DO, CD, DEM.
129	15	74	35	829	ND	ND	2	Y # open: 0 # total: 4	Y univent dust/ debris plant(s)	Y ceiling	CD, DEM, plants.

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									Supply	Exhaust	
130	0	72	37	777	ND	ND	2	Y # open: 0 # total: 6	Y univent items		Hallway DO, WD-other, damaged/missing window caulking/gasket, CD, DEM, PF, WD-window sill.
132	2	72	37	703	ND	ND	1	Y # open: 0 # total: 4	Y univent items	Y ceiling	CD, cleaners.
133	27	72	34	740	ND	ND	2	Y # open: 0 # total: 4	Y ceiling	Y ceiling	Hallway DO, #MT/AT : 1, CD, DEM.
134	0	72	39	836	ND	ND	2	Y # open: 0 # total: 6	Y univent plant(s)	Y ceiling	CD, DEM, items.
135	0	71	40	830	ND	ND	1	Y # open: 0 # total: 4	Y univent	Y ceiling location	DEM, items.

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									Supply	Exhaust	
136 (auditorium)	4	69	34	551	ND	ND	1	N # open: 0 # total: 0	Y ceiling	Y wall	

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